SeaSonde Measurements in COPE-3

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LONG-TERM GOALS

The long-range goals of this project are to validate the performance of high frequency (HF) radar as instruments for remote sensing of ocean surface currents. By collecting simultaneous measurements from independent HF radar systems, along with moored current observations, it is hoped that the accuracy of the remote measurements can be both determined and improved upon.

OBJECTIVES

This project is designed to take advantage of the field measurements undertaken as part of the third phase of the Chesapeake Outfall Plume Experiment (COPE-3). By deploying two SeaSonde, or CODAR-type, HF radar systems along the Virginia Beach coastline, these data can be compared with similar measurements from other HF radar instruments and moored observing platforms. These wide-ranging ocean current measurements can also be combined and compared with observations of the wind and tidal forcing fields to improve models of coastal circulation over shallow continental shelf areas.

APPROACH

The approach taken in this project was to collect ocean surface current measurements from SeaSonde HF radar instruments at two locations along the Virginia Beach coastline during COPE-3. These data were collected simultaneous to independent measurements by two Multi-frequency Coastal Radar (MCR) installations deployed by J. Vesecky of the University of Michigan and by two Ocean Surface Current Radar (OSCR) installations deployed by H. Graber of the University of Miami. At the same time, five bottom-mounted Acoustic Doppler Current Profilers (ADCPs) were deployed within the multi-radar observational domain by Z. Hallock of the Naval Research Laboratory. All measurements were conducted just to the south of the mouth of Chesapeake Bay during October and November of 1997.

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The hardware and software components of the three HF radar systems deployed are each unique. The most important differences are related to the antenna design and sampling strategies of the various systems. In particular, the SeaSonde is a CODAR-type system that employs compact, co-located antenna elements and direction-finding algorithms to determine the azimuthal direction from which ocean signals originate. By contrast, both the MCR and OSCR systems employ linear array receive antennas that require ~100m of straight coastline. The MCR software sub-systems have the capability of pointing using either phased-array or direction-finding techniques. Because of their small size and increased logistical flexibility, the two SeaSonde instruments were deployed from beach houses in Virginia Beach and Sandbridge, VA, which were in each case displaced about 3 km south of the military beach sites used by the MCR and OSCR teams. This was both convenient and necessary because the SeaSonde systems transmit and receive continually, whereas the other systems burst sample for a few minutes per hour.

Ocean backscatter data at nominally 25 MHz was collected by the SeaSonde units at 15-minute intervals. The range resolution of the systems were set to 1.5 km with maximum ranges achieved typically 40-50 km. The raw data was converted into hourly radial current estimates from each site, which in turn were combined to produce hourly vector current maps.

The experiment field activities also included dedicated calibration measurements for the SeaSonde (and MCR) HF radar systems. A small research vessel was leased with the aid of colleagues at Old Dominion University. The boat was used on two separate days to support transponder equipment designed to receive and re-transmit signals from either the SeaSonde or MCR sites. The transponders were taken to known offshore locations using GPS and compass-bearing navigation. Transponder data were collected over many angles on range rings from 0.75 km to 1.50 km. For the SeaSonde systems, transponder data at various angles was also collected from the beach within 100 m of the antennas. This information is required to determine antenna phase and amplitude corrections used in the radial current algorithms.

WORK COMPLETED

A successful field campaign was completed during the year in which two SeaSonde HF radar sites were occupied during COPE-3. The SeaSonde deployments were particularly successful in that the equipment was installed quickly and operated well for most of the 6-week experiment period. The data coverage in both time and range was quite good. The 15-minute radial currents produced by the systems were combined to create hourly and daily averaged vector maps. These data have been compared with wind forcing time series obtained from the Chesapeake Light Station. They have also been compared with preliminary results from the MCR systems and from moored ADCP data. Calibration data for the SeaSonde units was processed and all radial current files are being reprocessed so that future analyses will be based on more optimized current estimates.

RESULTS

This project succeeded to collect HF radar data from two SeaSonde instruments during COPE-3. A timeline of radial current data returns from the northern and southern SeaSonde sites is shown in Figure

1 together with similar data for the MCR systems. Except for one three-day period at the northern site when a system crash went undetected and a two-day period at the southern site when storm waves eroded the dunes and knocked down the antennas, both systems were operating continuously from 30 September to 18 November, 1997. Initial set-up for the two beach house locations was accomplished in about 24 hours, providing for an additional data collection period of about 10 days before the MCR or OSCR phased-array systems were installed.

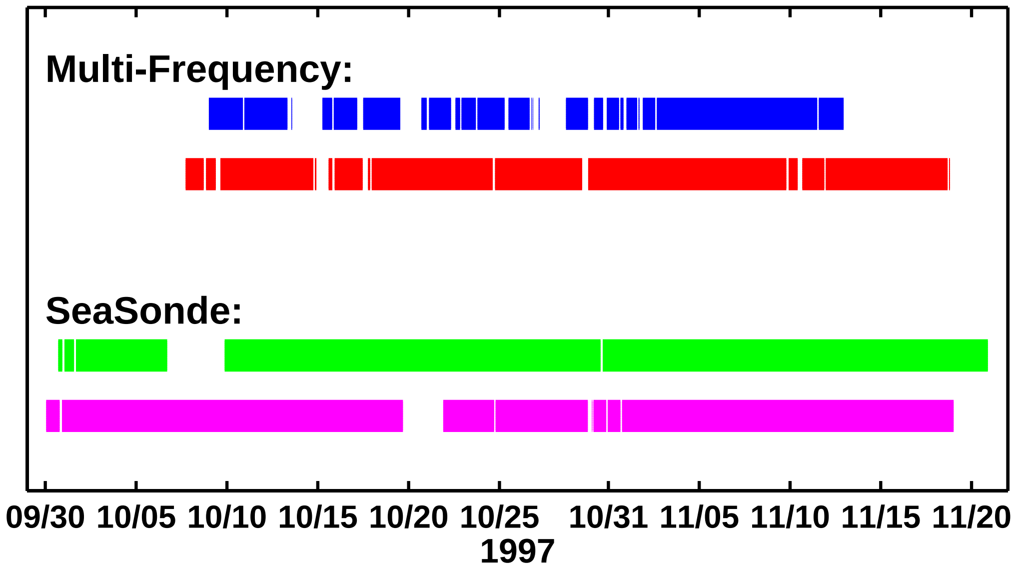

Figure 1. Timeline of radial current returns from COPE-3 for the University of Michigan MCR and the Naval Postgraduate School CODAR/SeaSonde systems at their respective northern (upper) and southern (lower) sites. Data returns from two OSCR sites (not shown) were similar to those of the MCR sites.

Initially, daily averaged surface current maps were produced from the SeaSonde data for comparison with synoptic wind forcing events. These events play a significant role in controlling sub-tidal-period currents on the continental shelf in this area, which was clear from the intial SeaSonde current maps. (The results were presented at the Ocean Sciences conference in San Diego in February 1998.) Often, the wind is observed to drive large-scale surface currents northward along the coast in opposition to the buoyant outflow from Chesapeake Bay. A good example occurred on October 25th following a strong southerly wind forcing event. The daily averaged currents for this day are shown in Figure 2, which shows a large-scale surface convergence in the vincinity of the outflow. The figure also illustrates the typical coverage attained by the two-site SeaSonde array as well as the location of the sites in relationship to the wind measurements and to one of the five ADCP moorings.

A number of analyses have been completed based on the preliminary COPE-3 data to assess the comparison between currents from the SeaSonde and MCR systems. Initial results are very encouraging. (Eventually, comparisons between these data and currents from the OSCR systems will also be conducted.) Time series and scatter plot comparisons between SeaSonde and MCR results at the mooring location shown in Figure 2 are presented in Figure 3. There are some biases between the output from the two independent systems, but the agreement is quite remarkable. Further investigation of the biases in relation to the differences in the two systems should lead to a better understanding of HF radar hardware and software.

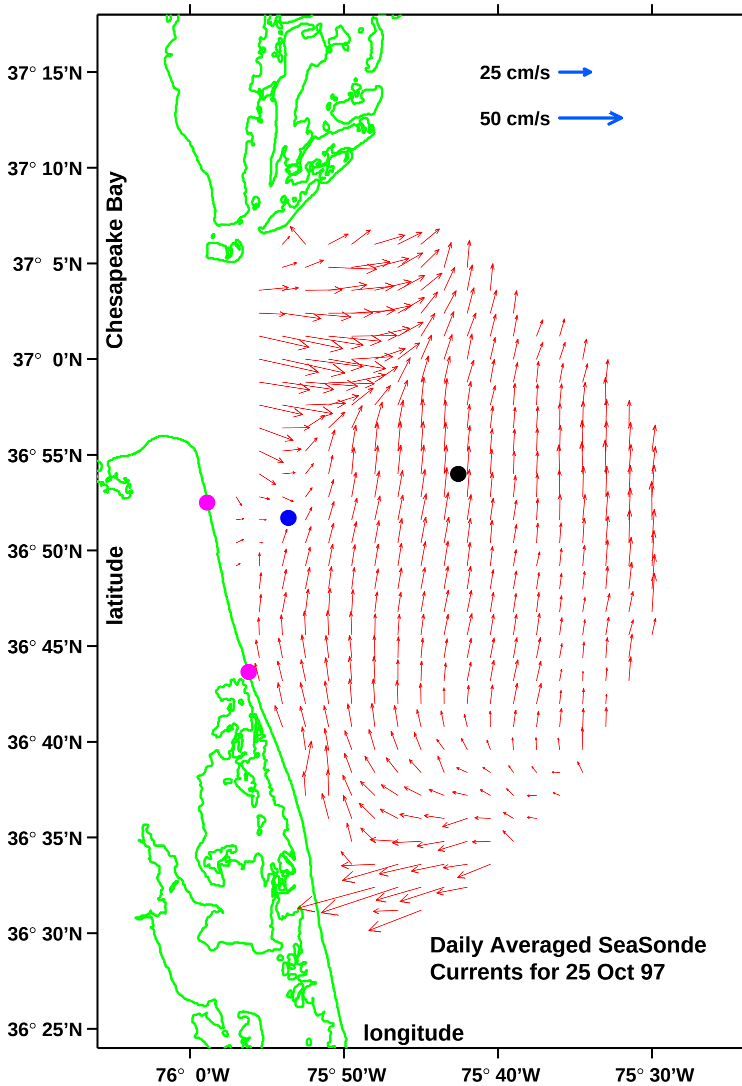

Figure 2. Daily averaged currents from the 2-site SeaSonde array (•) following a period of southerly wind forcing measured at the Chesapeake Light Station (•). Comparisons with MCR data at the second offshore ADCP mooring site (•) are shown below.

IMPACT/APPLICATIONS

The likely impact of this project will be to improve the algorithms used to compute surface ocean currents from HF radar backscatter and improve models of wind and buoyancy forcing of currents on the continental shelf. The simultaneous collection of data from three independent HF radar arrays and five ADCP moorings is unprecedented. The data collected from transponders constructed for the SeaSonde and MCR systems is also likely to lead to a protocol for calibrating any HF radar site, which has been lacking from most HF radar deployments to date.

TRANSITIONS

Our preliminary results have strengthened the case for HF radar measurements in the coastal ocean. The obvious transition target for this technology are groups within the Navy tasked with operating in the coastal ocean. HF radar deployments at training sites around the country are recommended as one

mechanism for introducing this technology to Fleet operations. Systems should also be deployed around busy Navy ports to improve current modeling and hazardous spill response in those areas. Long term, HF radar systems should be developed that can operate from ships at sea in order to increase deployment flexibility.

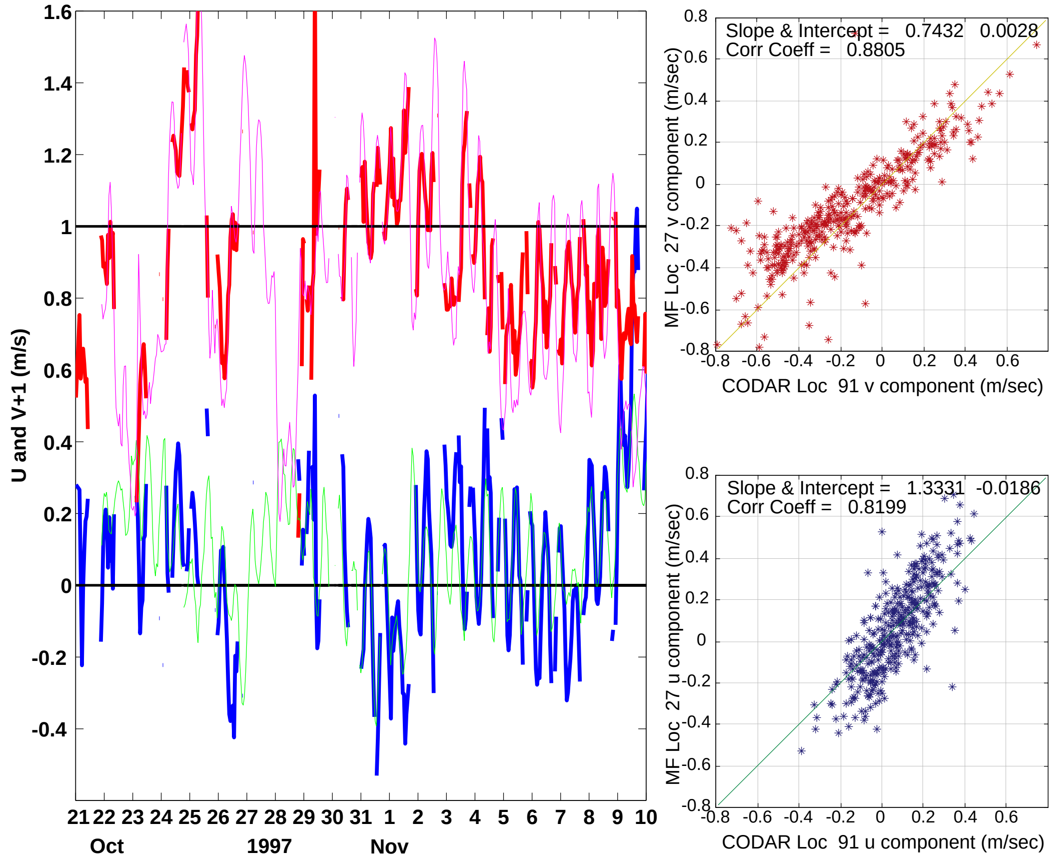

Figure 3. Surface current time series (left) at the location of the second offshore ADCP mooring in COPE-3 derived from the MCR (red and blue) and SeaSonde (magenta and green) HF radar systems using preliminary, uncalibrated data. Scatter plots (right) for the overlapping time points are also shown illustrating the significant correlations between the two data sets. RMS differences for these preliminary data are 15.2 cm/sec and 14.7 cm/sec for the u and v components, respectively.

RELATED PROJECTS

Of related interest to this project is the follow-on analysis program that will process the calibrated HF radar data from COPE-3 and continue the inter-comparisons between SeaSonde, MCR, and OSCR data, and between these data and the moored ADCP observations. Also of interest is the new program in Monterey Bay funded by the National Ocean Partnership Program (NOPP) that will utilize data from 3 SeaSonde units, 3 MCR units and 4 deep-ocean moorings as input to a coastal circulation model (http://www.oc.nps.navy.mil/~radlab/ICON/).

PUBLICATIONS

Teague, C.C., D.M. Fernandez, K.E. Laws, J.D. Paduan, and J.F. Vesecky, 1998: Comparison of Multifrequency Phased-Array and Direction-Finding HF Radar Systems during COPE-3. Proceedings, IEEE/IGARSS 98, Seattle.